UNIVERSITI MALAYSIA KELANTAN

Preparation of ZnO/GO composite using a hydrothermal method for semiconductor material

Muhammad Khairul Fitri Bin Mohd Zuki
J20A0519

A reported submitted in fulfilment of the requirements for the degree of Bachelor of Applied Science (Materials Technology) with Honours

FACULTY OF BIOENGINEERING AND TECHNOLOGY

UMK

2024

DECLARATION

I declare that this thesis entitled “Preparation of ZnO/GO composite using a hydrothermal method for semiconductor material” is the results of my own research except as cited in the references.

Signature :

Student’s Name : MUHAMMAD KHAIRUL FITRI BIN MOHD ZUKI

Date :

Verified by:

Signature :

Supervisor’s Name :

Stamp :

Date :

ACKNOWLEDGEMENT

First and foremost, I want to thank Allah SWT for providing me with the opportunity and excellent health, both mentally and physically, to complete my Final Year Project. I'd want to thank my supervisor, Dr Arlina Bt Ali, for her support, sharing her advice and knowledge in this project, and for allowing me to conduct research on a topic that is very important to me. His zeal in teaching me how to complete my final year project was invaluable, and I am grateful for everything he has done for me. His mentoring helped me finish my FYP, and I am grateful to have an excellent supervisor like Dr. Arlina.

I would also want to thank Ts. Hanisah Izati Binti Adli for her laboratory help in allowing me to do research at the Materials Science Laboratory. With his provisions and direction in the laboratory, he can properly conduct experiments and avoid laboratory accidents. Much gratitude is also due to Dr. An'amt Bin Mohamed Noor for lending me the autoclave, as well as Ms. Syahirah Binti Sanadee and Ms. Nurul Idayu Akma Binti Khairul Anuar for their assistance with laboratory work; without them, I would not have been able to complete my FYP.

Also, special thanks to all of my friends who encouraged me to conduct study. They also gave me everything I needed to finish my research and thesis writing. Without a doubt, none of this would have been possible without the help of my family, particularly my parents, who always pay attention to me and provide moral support as I work on my education.

PREPARATION OF ZNO/GO COMPOSITE USING A HYDROTHERMAL METHOD FOR SEMICONDUCTOR MATERIAL

ABSTRACT

This research addresses the imperative to enhance semiconductor materials to meet the escalating demands of modern technological applications. Specifically, it focuses on the efficient preparation of ZnO/GO composites via a hydrothermal method, targeting advancements in semiconductor properties. The study aims to elucidate the synergistic effects of combining ZnO and graphene oxide (GO) and to control their structural and optical properties for applications in optoelectronics, solar cells, sensors, and catalysis. The investigation involves the preparation of ZnO–GO composites with varying amounts of GO, followed by morphological, crystalline, and optical characterization. The process entails the synthesis of ZnO/GO composites through a series of steps, including solution preparation, autoclaving, and drying. Results indicate the potential of ZnO/GO composites to exhibit enhanced semiconductor capabilities, paving the way for future technological advancements. The controllable nature of the hydrothermal process offers scalability and promising avenues for further research and development in Materials Technology. This research contributes significantly to the field of semiconductor materials and lays the groundwork for future innovations in composite materials for diverse technological applications.

PREPARATION OF ZNO/GO COMPOSITE USING A HYDROTHERMAL METHOD FOR SEMICONDUCTOR MATERIAL

ABSTRAK

Penyelidikan ini menangani keperluan untuk meningkatkan bahan semikonduktor untuk memenuhi permintaan yang semakin meningkat bagi aplikasi teknologi moden. Secara khusus, ia memberi tumpuan kepada penyediaan komposit ZnO/GO yang cekap melalui kaedah hidroterma, menyasarkan kemajuan dalam sifat semikonduktor. Kajian ini bertujuan untuk menjelaskan kesan sinergistik menggabungkan ZnO dan graphene oxide (GO) dan untuk mengawal sifat struktur dan optik mereka untuk aplikasi dalam optoelektronik, sel suria, penderia, dan pemangkinan. Penyiasatan melibatkan penyediaan komposit ZnO-GO dengan jumlah GO yang berbeza-beza, diikuti dengan pencirian morfologi, kristal dan optik. Proses ini memerlukan sintesis komposit ZnO/GO melalui satu siri langkah, termasuk penyediaan larutan, autoklaf dan pengeringan. Keputusan menunjukkan potensi komposit ZnO/GO untuk mempamerkan keupayaan semikonduktor yang dipertingkatkan, membuka jalan untuk kemajuan teknologi masa hadapan. Sifat terkawal proses hidroterma menawarkan kebolehskalaan dan jalan yang menjanjikan untuk penyelidikan dan pembangunan lanjut dalam Teknologi Bahan. Penyelidikan ini menyumbang secara signifikan kepada bidang bahan semikonduktor dan meletakkan asas untuk inovasi masa depan dalam bahan komposit untuk aplikasi teknologi yang pelbagai.

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CHAPTER 1

INTRODUCTION

1.1 Background of Study

As the foundation of the numerous electronic devices we use every day, semiconductors play a crucial role in the present technological landscape. These extraordinary materials, frequently made of silicon, have special electrical characteristics that allow them to partially conduct electricity. They are necessary for the development of transistors, the fundamental components of digital circuits, because of their capacity to change between conducting and insulating states when subjected to an electric field. The ability to amplify, manipulate and process electrical signals with high precision has been discovered thanks to the intelligent integration of these small semiconductor components, revolutionizing sectors such as computing, telecommunications and renewable energy. The advent of the digital age and the resulting worldwide network of networked devices that improve our lives in unfathomable ways were made possible by semiconductors.

Due to its distinctive features, zinc oxide, a versatile substance with a long history of usage, has become an intriguing material in many domains. This white, powdery compound, which is made of zinc and oxygen atoms, has received a lot of attention for its diverse range of applications, which include electronics, medicine, and more. Zinc oxide has a unique niche in optoelectronics thanks to its high refractive index, transparency, and light-to-electricity conversion capabilities. It is a crucial component of solar cells and transparent conductive coatings. Its antimicrobial qualities have also made it a well-liked element in cosmetics, medicines, and even textile industries. Additionally, zinc oxide's broad bandgap enables it to act as a semiconductor, making it appropriate for use in sensors, transistors, and light-emitting diodes (LEDs). Zinc oxide has demonstrated its capacity to revolutionise a variety of industries, progress technology, and improve our daily lives through continual research and innovation.

Due to its excellent qualities and possible applications, graphene oxide, a unique derivative of graphene, has attracted a lot of interest in the scientific world. Graphene oxide is derived from graphene, a single layer of carbon atoms organised in a two-dimensional honeycomb lattice. By oxidising graphene, oxygen-containing functional groups are added to its surface. Through this process, a material is created that has exceptional mechanical strength, strong electrical conductivity, and amazing thermal stability. A viable option for use in a variety of industries, including energy storage, electronics, biomedical engineering, and environmental remediation, graphene oxide demonstrates intriguing qualities like large surface area and dispersibility in water (Li H. C., 2020). Due to its adaptability, it can be utilised to create supercapacitors, sensors, medicine delivery systems, and water filtration systems. Graphene oxide has remarkable qualities and a broad range of possible applications, making research into this material interesting. Researchers are constantly looking for new methods to use graphene oxide's capabilities to enhance a variety of fields and technological advancements.

In order to generate a hybrid substance that has great potential in a variety of scientific and technological fields, zinc oxide and graphene oxide are combined. Each astonishing material has its own special qualities. The excellent mechanical strength, high electrical conductivity, and surface functionalization of graphene oxide is complemented by zinc oxide, which is well known for its transparency, high refractive index, and semiconducting properties. To create new materials and gadgets, researchers can combine various elements and take use of the synergistic benefits. Flexible electronics, energy storage systems, and environmental sensing are just a few of the applications that can benefit from the addition of graphene oxide to zinc oxide matrices (Ding, 2015). In addition to higher electrical conductivity, this mixture also benefits from graphene oxide's superior surface area and dispersibility. With the potential to revolutionise numerous industries and propel developments in areas ranging from electronics and energy to healthcare and environmental monitoring, the combination of zinc oxide and graphene oxide presents an intriguing new path for innovation (Kachere, 2021, August 26).

1.2 Problem Statement

Despite the advancements in semiconductor materials, there is a need to explore innovative methods for enhancing their properties to meet the demands of emerging technological applications. The current research gap lies in the efficient preparation of ZnO/GO composites using a hydrothermal method for semiconductor materials. Understanding the synergistic effects of combining ZnO and graphene oxide (GO) in composites and controlling their structural and optical properties is crucial for developing high-performance devices in optoelectronics, solar cells, sensors, and catalysis. Therefore, there is a pressing need to investigate the potential of ZnO/GO composites to exhibit enhanced semiconductor capabilities and pave the way for future technological advancements in the field of Materials Technology.

1.3 Objectives

The objectives of this research are:

1. To prepare ZnO–GO composites using hydrothermal method with different amount of GO.
2. To characterize the morphology, crystallinity, and optical properties ZnO–GO composites.

1.4 Scope of Study

The scope of research on the preparation of Zinc Oxide/Graphene Oxide (ZnO/GO) composites using the hydrothermal method for semiconductor materials is broad and includes various aspects. First, the scope lies in understanding the fundamental mechanisms and kinetics involved in the hydrothermal preparation of ZnO/GO composites. Researchers can investigate the influence of different reaction parameters such as morphology, crystallinity, and optical properties of ZnO–GO composites. By systematically studying these variables, valuable insights can be gained into the formation and growth of ZnO nanoparticles on GO surfaces, leading to optimized composite structures with enhanced semiconductor properties.

Second, the scope includes exploring the applications of prepared ZnO/GO composites in semiconductor devices and technologies. This involves studying its performance in specific applications such as photovoltaics, optoelectronics, sensors and catalysis. Researchers can investigate the composite's charge transport properties, bandgap engineering and sensitivity to external stimuli to assess its suitability for different device architectures and operating conditions. By identifying the strengths and limitations of ZnO/GO composites in various applications, researchers can contribute to the development of more efficient and versatile semiconductor devices.

1.5 Significances of Study

In the field of semiconductor materials, the investigation of the hydrothermal method for producing Zinc Oxide/Graphene Oxide (ZnO/GO) composites is of great significance. This line of inquiry investigates how ZnO and GO, two materials with different properties, might be combined in a synergistic way to produce a composite with improved semiconductor capabilities. The fabrication of the composite using the hydrothermal process is controllable and scalable, allowing for fine control over the integration of ZnO nanoparticles onto the GO surface. Researchers can obtain a homogeneous distribution of ZnO nanoparticles, resulting in increased electrical conductivity and optical characteristics, by comprehending and optimising the synthesis conditions. The ZnO/GO composite can be used to create high-performance devices in the fields of optoelectronics, solar cells, sensors, and catalysis as a result of this study. The results of this study also contribute to the broader field of semiconductor material science, bringing up new avenues for production methods and broadening the selection of useful materials for upcoming technological developments.

CHAPTER 2

LITERATURE REVIEW

2.1 Semiconductor Material

Semiconductor materials are a critical component of modern electronics and play a pivotal role in numerous technological advancements. These materials possess unique properties that make them capable of controlling the flow of electrical current with great precision, making them indispensable in devices like transistors, diodes, solar cells, and integrated circuits.

Semiconductors are characterized by their intermediate conductivity, lying between conductors (such as metals) and insulators (such as non-conductive materials). This behavior arises from the presence of an energy bandgap a range of energy levels that separates the valence band (where electrons are bound to atoms) from the conduction band (where electrons can move freely).

One of the most widely used semiconductor materials is Silicon (Si). Silicon has a crystalline structure and is abundant in nature, making it cost-effective and readily available. It possesses several desirable properties, including a moderate bandgap energy and excellent thermal stability (Faisal, 2018). Silicon forms the basis of the vast majority of electronic devices and integrated circuits, owing to its reliability and compatibility with existing manufacturing processes.

However, there are also other semiconductor materials with unique characteristics that find specific applications. For instance, Gallium Arsenide (GaAs) exhibits a higher electron mobility than silicon, making it well-suited for high-frequency and high-speed electronic devices. GaAs is commonly used in telecommunications, microwave circuits, and optoelectronic devices.

Moreover, compound semiconductors like Gallium Nitride (GaN) and Indium Gallium Nitride (InGaN) offer wide bandgap energies, enabling efficient operation at high power levels and in harsh environments. These materials are employed in applications such as light-emitting diodes (LEDs), power electronics, and wireless communications.

In recent years, there has been growing interest in exploring novel semiconductor materials, including organic semiconductors and perovskite materials. Organic semiconductors offer advantages like flexibility, low-cost production, and large-area coverage, making them suitable for applications such as organic solar cells, flexible displays, and printed electronics. Perovskite materials, with their exceptional optoelectronic properties, have emerged as promising candidates for efficient solar cells and next-generation light-emitting devices.

In conclusion, semiconductor materials form the foundation of modern electronics and technology. Their unique properties and ability to control electrical current make them indispensable in a wide range of applications. Whether it's Silicon, Gallium Arsenide, Indium Phosphide, or emerging materials like organic semiconductors and perovskites, each semiconductor material offers specific advantages and opens up new possibilities for innovation and advancement in various fields.

2.2 ZnO/GO Composite

A ZnO/GO composite is a fascinating and promising material that combines the unique properties of Zinc Oxide (ZnO) and Graphene Oxide (GO) to create a versatile and functional composite material. The composite is prepared by integrating ZnO nanoparticles with GO sheets using a variety of synthesis methods, such as the hydrothermal method or chemical vapor deposition (Ding, 2015).

ZnO is a wide-bandgap semiconductor material with excellent electrical and optical properties. It exhibits a hexagonal wurtzite crystal structure and is transparent in the visible region, making it suitable for optoelectronic applications. ZnO is known for its high electron mobility, good thermal stability, and strong piezoelectric properties. These characteristics make it attractive for various fields, including sensors, solar cells, optoelectronic devices, and catalysis (Faisal, 2018).

GO, on the other hand, is a derivative of graphene, which is a two-dimensional carbon allotrope. GO consists of graphene sheets that are oxidized and functionalized with oxygen-containing groups, resulting in a hydrophilic and dispersible form. GO possesses exceptional mechanical strength, high electrical conductivity, and a large surface area, making it a desirable material for energy storage, flexible electronics, and composite reinforcement (Kachere, 2021, August 26).

When ZnO and GO are combined in a composite structure, their individual properties synergistically enhance the overall performance. The homogeneous distribution of ZnO nanoparticles on the GO surface results in improved electrical and optical properties of the composite (Kachere, 2021, August 26). The GO sheets serve as a scaffold for the ZnO nanoparticles, preventing their aggregation and promoting uniform dispersion. This arrangement provides an increased interfacial area, facilitating efficient charge transfer and improving the overall conductivity of the composite.

Moreover, the incorporation of GO within the ZnO matrix can modify the structural and mechanical properties of the composite. GO acts as a filler, reinforcing the composite material and improving its mechanical strength and flexibility. The layered structure of GO can also provide barrier properties, preventing the penetration of moisture and other external contaminants, thereby enhancing the composite's stability and durability.

The ZnO/GO composite holds significant potential for a wide range of applications. In optoelectronics, the composite's enhanced electrical conductivity and light absorption properties make it suitable for solar cells, photodetectors, and light-emitting devices. In energy storage, the high surface area of GO promotes efficient ion diffusion, making the composite an excellent candidate for supercapacitors and batteries. The composite's mechanical strength and flexibility are advantageous for flexible electronics and wearable devices (Salih, 2016). Additionally, the composite can be utilized in catalysis, where the ZnO nanoparticles supported on the GO surface provide a high catalytic activity and stability.

In summary, the ZnO/GO composite represents a remarkable combination of two distinct materials, harnessing the unique properties of both ZnO and GO. This composite exhibit improved electrical conductivity, optical properties, mechanical strength, and structural stability. With its diverse range of applications in electronics, energy, and catalysis, the ZnO/GO composite holds tremendous promise for advancing technology and driving innovation in various fields.

2.3 Zinc chloride

Zinc chloride (ZnCl2) is a versatile compound with a wide range of applications spanning various industries, including pharmaceuticals, chemical synthesis, metallurgy, and even in the realm of batteries. Its unique properties make it a valuable ingredient in many processes and products. One notable application of zinc chloride is its role as a catalyst in organic synthesis. Researchers have extensively explored its catalytic activity in numerous reactions, such as the Friedel-Crafts acylation and alkylation, where it serves as a Lewis acid catalyst, facilitating the formation of carbon-carbon bonds.

In pharmaceuticals, zinc chloride has shown promise in medicinal formulations. Studies have highlighted its antimicrobial properties, making it an effective ingredient in mouthwashes, throat lozenges, and other oral hygiene products. Additionally, zinc chloride has been investigated for its potential in dermatological applications, including as an astringent and antiseptic agent in skin care products. Its ability to promote wound healing and regulate sebum production has garnered significant interest in the cosmetic industry.

In the field of metallurgy, zinc chloride plays a crucial role in galvanizing processes. By forming a protective layer on metal surfaces, it helps prevent corrosion and extends the lifespan of various metallic components, from automotive parts to structural elements. Furthermore, zinc chloride is utilized in fluxes for soldering and welding applications, where it aids in removing oxides from metal surfaces, ensuring strong and clean joints.

Beyond its industrial applications, zinc chloride has emerged as a key component in advanced battery technologies. Research efforts have focused on utilizing zinc chloride-based electrolytes in rechargeable zinc-ion batteries, which offer promising alternatives to traditional lithium-ion batteries due to their lower cost, higher energy density, and reduced environmental impact. Investigations into optimizing the performance and stability of zinc chloride electrolytes are ongoing, with the aim of advancing the commercial viability of these next-generation energy storage systems.

Overall, the diverse range of applications and the unique properties of zinc chloride underscore its significance in various fields of science and industry. Continued research and innovation in the synthesis, characterization, and application of zinc chloride hold the potential to unlock further benefits and expand its utility in the years to come.

Figure 2.3: Zinc chloride

2.4 Sodium hydroxide

Sodium hydroxide (NaOH), commonly known as caustic soda or lye, is a highly versatile compound with a wide range of industrial, commercial, and domestic applications. Its chemical formula, NaOH, reflects its composition of sodium (Na), hydrogen (H), and oxygen (O). This compound is primarily known for its strong alkaline properties, characterized by a high pH level, making it a cornerstone in various chemical processes and industries.

In terms of its properties, sodium hydroxide is a white, odorless, and highly hygroscopic solid at room temperature. It is soluble in water and produces a highly exothermic reaction, generating heat when dissolved. This characteristic renders it useful in various chemical reactions, including neutralization and saponification processes. Additionally, sodium hydroxide is corrosive to organic tissues and is handled with caution due to its potential for causing severe burns upon contact.

The applications of sodium hydroxide span across numerous industries, showcasing its importance in modern manufacturing processes. One prominent application is in the production of soaps and detergents, where sodium hydroxide acts as a key ingredient in the saponification process, converting fats and oils into soap molecules. Furthermore, it is extensively used in the pulp and paper industry for delignification during the production of paper, as well as in the textile industry for mercerization of fabrics, enhancing their strength and luster. Moreover, sodium hydroxide finds utility in water treatment processes for pH adjustment and as a reagent in the synthesis of various chemicals, including pharmaceuticals and polymers.

Despite its widespread use, the environmental implications of sodium hydroxide cannot be overlooked. Its production involves energy-intensive processes, contributing to greenhouse gas emissions and environmental degradation. Moreover, improper disposal of sodium hydroxide-containing waste can lead to water and soil contamination, posing risks to aquatic ecosystems and human health. Efforts are thus underway to develop more sustainable production methods and effective waste management strategies to mitigate the environmental impact associated with sodium hydroxide usage.

In conclusion, sodium hydroxide is a crucial chemical compound with diverse applications across industries, owing to its strong alkaline properties and reactivity. While its utility in various manufacturing processes is undeniable, attention must be given to its environmental ramifications, emphasizing the importance of sustainable practices and responsible waste management in sodium hydroxide-related industries.

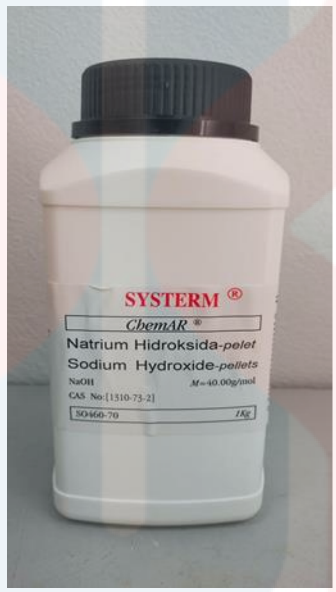


Figure 2.4: Sodium hydroxide

2.5 Graphene oxide

Graphene oxide (GO) has emerged as a fascinating material with a myriad of potential applications, owing to its unique properties and versatile characteristics. Initially discovered through the oxidation of graphite, GO possesses a two-dimensional structure comprising oxygen-functionalized graphene sheets. This material has garnered significant attention in various fields, including electronics, energy storage, biomedical engineering, and environmental remediation. In the realm of electronics, GO exhibits exceptional electrical conductivity and mechanical strength, making it a promising candidate for next-generation electronic devices. Furthermore, its high surface area and tunable surface chemistry render it ideal for applications in energy storage systems such as supercapacitors and batteries. In biomedical engineering, the biocompatibility and large surface area of GO have spurred research into drug delivery systems, biosensors, and tissue engineering scaffolds. Additionally, the facile functionalization of GO enables the incorporation of targeting ligands and therapeutic agents, enhancing its potential in targeted drug delivery. Moreover, GO-based materials have shown remarkable efficacy in environmental applications, including pollutant removal, water purification, and catalysis. The unique physicochemical properties of GO facilitate efficient adsorption and degradation of contaminants, offering sustainable solutions to environmental challenges. Overall, the extensive research on graphene oxide underscores its versatility and immense potential across diverse fields, heralding a new era of innovation and discovery in materials science and engineering.

2.6 Hydrothermal Method

The hydrothermal method is a versatile and widely used technique in materials synthesis and fabrication. It involves the controlled growth and formation of materials in an aqueous solution under elevated temperature and pressure conditions. This method has gained significant popularity due to its simplicity, scalability, and ability to produce a wide range of materials with desirable properties.

The hydrothermal process begins with the preparation of a precursor solution containing the desired reactants, which may include metal salts, organic compounds, or nanoparticles. The solution is then sealed inside a pressure vessel, typically made of stainless steel or Teflon, and heated to the desired temperature using an external heat source such as an oven or autoclave.

The elevated temperature and pressure conditions within the sealed vessel create a unique environment that promotes chemical reactions and facilitates the formation of desired materials. The water present in the solution acts as both a solvent and a reactant, playing a crucial role in the synthesis process. It provides a medium for the dissolution, diffusion, and reaction of the precursors, allowing for the growth of crystals, nanoparticles, or thin films.

The hydrothermal method offers several advantages over other synthesis techniques. Firstly, it enables the formation of materials with controlled size, morphology, and crystallinity (Ding, 2015). The temperature and pressure conditions can be precisely adjusted to tailor the properties of the synthesized materials. Additionally, the hydrothermal process allows for the uniform distribution of nanoparticles or other components within the resulting material, leading to enhanced properties and performance.

Moreover, the hydrothermal method is known for its versatility, as it can be applied to a wide range of materials including oxides, sulphides, hydroxides, and composites. It has been extensively utilized in the synthesis of various functional materials such as nanoparticles, nanowires, thin films, and nanostructures. Furthermore, the hydrothermal process can be easily scaled up for industrial production, making it suitable for large-scale manufacturing of materials.

Despite its many advantages, the hydrothermal method also has certain limitations and challenges. Controlling the reaction conditions, such as temperature, pressure, and reaction time, is crucial to achieve desired material properties. The choice of precursors, solvent, and reaction conditions requires careful optimization to prevent unwanted side reactions or phase transformations. Additionally, the hydrothermal process may require specialized equipment and safety precautions due to the high-pressure and high-temperature conditions involved.

In conclusion, the hydrothermal method is a powerful and versatile technique for materials synthesis. It offers precise control over the growth and formation of materials, allowing for the production of tailored materials with improved properties. With its wide range of applications and scalability, the hydrothermal method continues to contribute significantly to the advancement of various fields, including materials science, chemistry, nanotechnology, and energy research.

CHAPTER 3

MATERIALS AND METHODS

3.1 Materials

In this study, zinc oxide (ZnO), graphene oxide (GO), and sodium hydroxide (NaOH) were all used as materials. Zinc oxide is preferred. R&M is the name of the company. The hazard type is Environmental Toxic, and the chemical formula is ZnO. It is owned by the Faculty. The Charge Number for this substance is 1314-13-2 and the content is 500 g. Next, graphene oxide. The chemical name for the product is C140H42O20, and the brand name is Sigma. It is owned by the Faculty. The Charge Number for this substance is 1034343-98-0 and the content is 200 mL. Sodium Hydroxide is another. HmbG is a trademarked name. Corrosive is a hazard category, and its chemical formula is NaOH. It is owned by the Faculty. The Charge Number for this substance is 1310-73-2 and the content is 1000 g.

3.2 Methods

For the preparation of ZnO/GO composites, 1 mol of ZnO = zinc chloride (ZnCl2), sodium hydroxide (NaOH) and different amounts of graphene oxide (GO), shown in table 3.0. Then, stir the solution at room temperature for 30 minutes. Then, put it in an autoclave that has been lined with Teflon. Next, a hot air oven is used to heat the autoclave at 180°C for 6 hours before cooling to room temperature. The final product is filtered and washed using distilled water and then dried in an oven at a temperature of 90°C for 2 hours to produce a ZnO/GO composite. Finally, analyze the data and write a report.

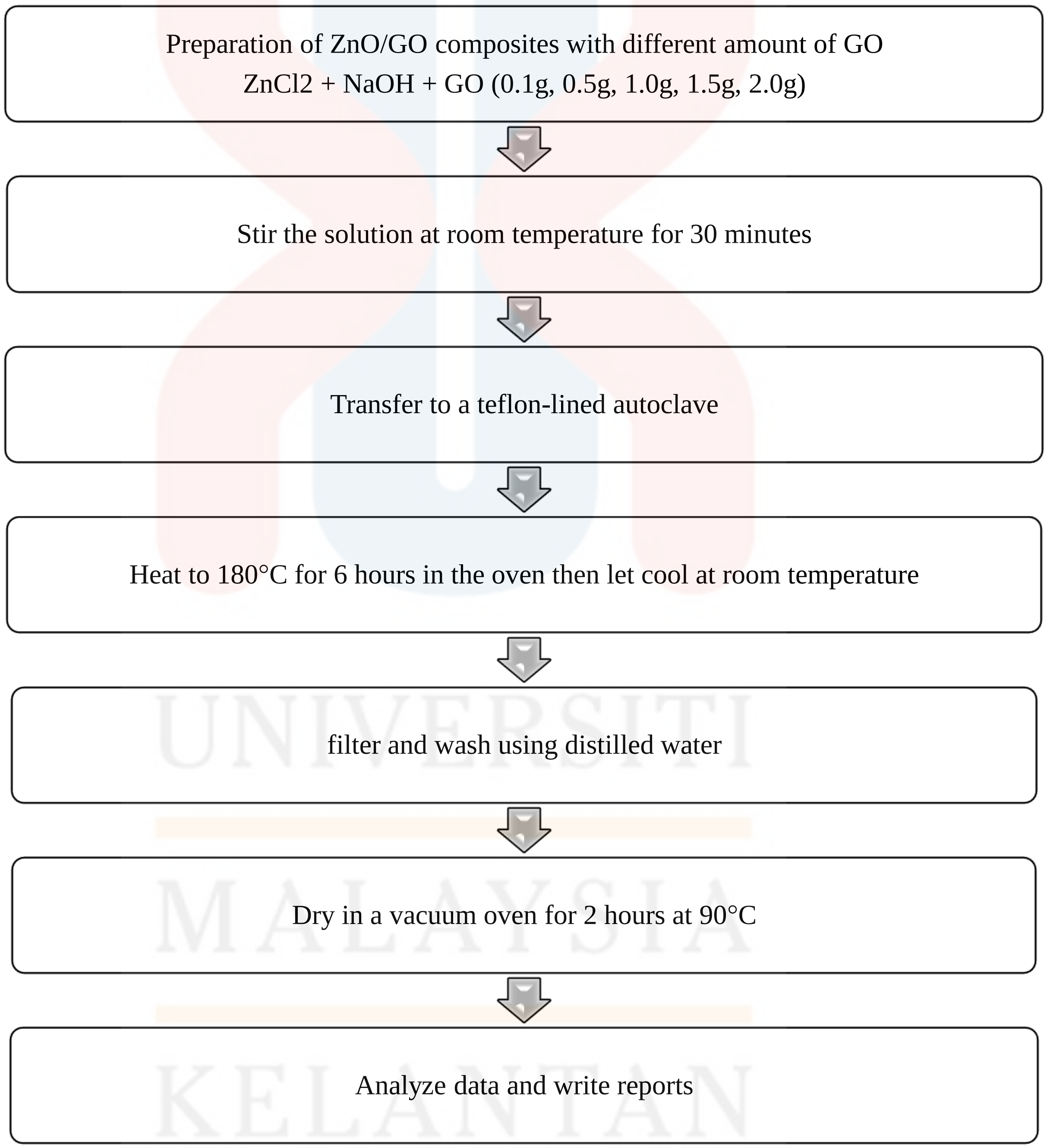


Figure 3.2: Research process preparation ZnO/GO composite

Table 3: The sample code and amount of ZnO and GO composite

Sample Codes	ZnO (gram)	GO (gram)
ZG0.1	1	0.1
ZG0.5	1	0.5
ZG1.0	1	1.0
ZG1.5	1	1.5
ZG2.0	1	2.0

3.2.1 X-ray Diffraction (XRD) Technique

Analysing the crystal structure and phase composition of materials is done using the potent characterisation technique known as X-ray Diffraction (XRD). Diffraction patterns are created by the interaction of X-rays with a sample's crystalline lattice. X-ray diffraction analysis (XRD) involves shining a monochromatic X-ray beam at the sample, collecting, and examining the diffraction pattern that emerges. The orientation of the sample, the lattice parameters, and the crystal structure may all be learned a great deal by observing the angles and intensities of the diffracted X-rays. Widespread applications of XRD include the identification of several phases in a material, estimation of their relative abundance, and evaluation of crystallinity. Studying crystalline materials, such as minerals, metals, ceramics, and medicinal compounds, benefits greatly from this technique.

3.2.2 UV-Vis Spectroscopy Testing

A popular characterisation method that offers useful insights into the electrical structure and optical characteristics of materials is UV-Vis spectroscopy. It entails evaluating a sample's transmission or absorption of UV and visible light throughout a spectrum of wavelengths. In UV-Vis spectroscopy, a beam of light is sent through the sample, and the amount of light that passes through or is absorbed by the sample is measured. The electronic transitions, energy bandgaps, and existence of chromophores in the sample can be discovered by examining the absorption or transmission spectrum. When determining the quantity of chromophores in a solution or the degree of light absorption by a solid material, UV-Vis spectroscopy is especially helpful.

CHAPTER 4

RESULTS AND DISCUSSION

4.1 Introduction

According to the goal of this study, the amount of GO varies from 0.1 g to 2.0 g of ZnO nanostructures obtained using the hydrothermal process. All ZnO/GO samples were analysed using X-ray Diffraction (XRD) and UV-Vis Spectroscopy (UV-Vis). This characterization test was designed to investigate the structure, absorption band, and optical properties of ZnO/GO nanostructures. X-ray diffraction (XRD) is used to identify phases in crystalline materials. UV-Vis Spectroscopy involves studying the visible section of the electromagnetic spectrum to discover band gaps.

4.2 X-ray Diffraction (XRD)

The figure 4.2 shows the X-ray diffraction (XRD) patterns of five samples: ZG2.0, ZG1.5, ZG1.0, ZG0.5, and ZG0.1. The X-ray diffraction pattern is a plot of intensity versus 2θ, where θ is the angle of incidence of the X-rays. The peaks in the pattern correspond to the different crystal planes in the sample. The intensity of each peak is proportional to the number of atoms that are diffracting X-rays in that plane.

The XRD patterns in the figure 4.2 show that all five samples have the same basic structure, but the intensity of the peaks varies depending on the GO weight fraction. The intensity of the ZnO peaks decreases as the GO weight fraction increases, while the intensity of the GO peaks at around

$2\theta = 10°$ increases. This indicates that the GO is disrupting the crystallinity of the ZnO. The GO sheets are likely intercalating between the ZnO layers, preventing the ZnO atoms from packing as closely together. This disruption in the crystal structure leads to a decrease in the intensity of the ZnO peaks.

The figure 4.2 also shows that the GO peak becomes broader and weaker as the GO weight fraction decreases. This is because the GO sheets are more stacked and ordered at higher weight fractions. When the GO weight fraction is lower, the GO sheets are more dispersed and less ordered, which leads to a broader and weaker peak.

Overall, the XRD patterns in the figure 4.2 show that the GO is disrupting the crystallinity of the ZnO. The degree of disruption depends on the GO weight fraction. These results suggest that the GO could be used to control the properties of ZnO-based materials.

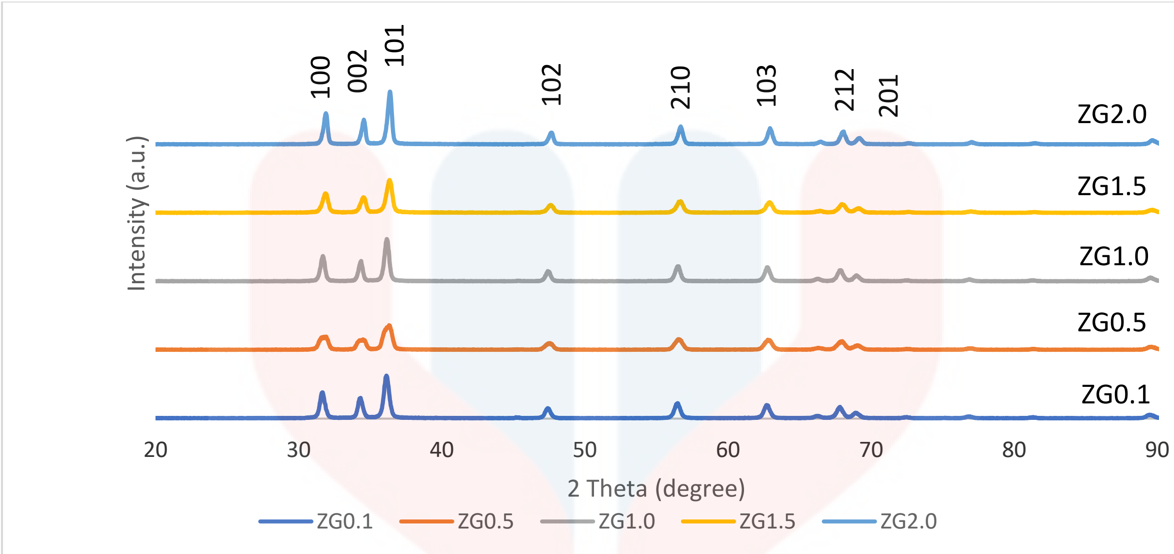


Figure 4.2: XRD patterns of ZnO nanostructure prepared at different amount of GO via hyrothermal method.

Table 4.2: The unit cell parameters of ZnO with different temperature

Sample	Lattice parameter			A/B ratio	C/A ratio	Crystallite size (D), nm
	A	B	C			
ZG0.1	3.2495	3.2495	5.2069	1	1.6024	18.71
ZG0.5	3.249	3.249	5.207	1	1.6026	12.70
ZG1.0	3.2495	3.2495	5.2069	1	1.6024	21.31
ZG1.5	3.249	3.249	5.207	1	1.6026	17.12
ZG2.0	3.249	3.249	5.207	1	1.6026	23.26

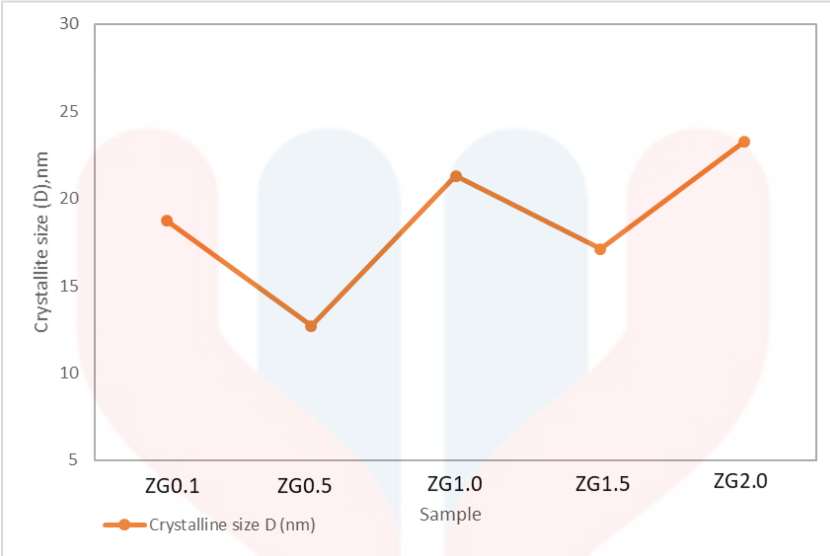


Figure 4.2.1: Graph of Crystallite size

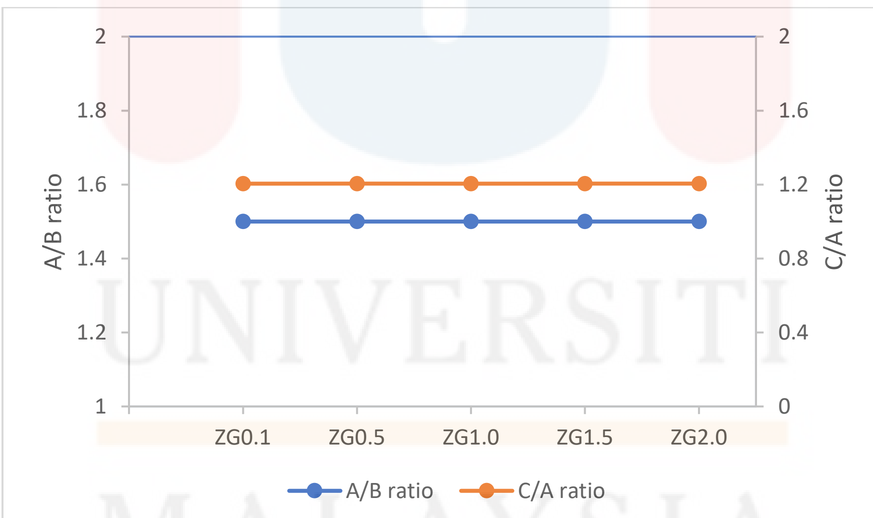


Figure 4.2.2: Graph of Lattice parameter

The average crystallite size of ZnO with different amount of GO was calculated using Scherer.

Formula as shown in Equation 4.1:

Convert the observed peak position, °2theta, into d_{hkl} values using Braggs' Law

$$D = \frac{\mathrm{k}\,\lambda}{\mathrm{d}\cos\theta}$$

Equation 4.1

For CuKα 1, the crystallite size is 0.15406 nm. A decent approximation for the crystallite form factor is 0.9. The FWHM value is d, and the angle is θ in radians. Table 2 displays the various crystallite sizes for ZnO with varied GO quantities of 0.1 g, 0.5 g, 1.0 g, 1.5 g, and 2.0 g at 18.17, 12.70, 21.31, 17.12, and 23.26 nm, respectively. According to the table, the average crystallite size in ZnO nanostructures is 18.62 nm.

4.3 Ultraviolet–Visible Spectroscopy (UV-Vis)

The figure shows the average absorption rate of different wavelengths of light. The x-axis shows the wavelength in nanometers (nm) and the y-axis shows the absorbance. The absorbance is a measure of how much light is absorbed by a material. An absorbance of 0 means that all the light is transmitted and an absorbance of 1 means that all the light is absorbed.

The graph shows that the absorption rate of light varies depending on the wavelength. In general, shorter wavelengths of light are absorbed more than longer wavelengths. This is why blue light appears dimmer than red light.

The specific absorption rate of light also depends on the material it is passing through. For example, water absorbs more blue light than red light, which is why water appears blue.

The absorption of light is an important property of materials and has many applications. For example, the absorption of light is used to create colored filters, sunglasses, and solar cells.

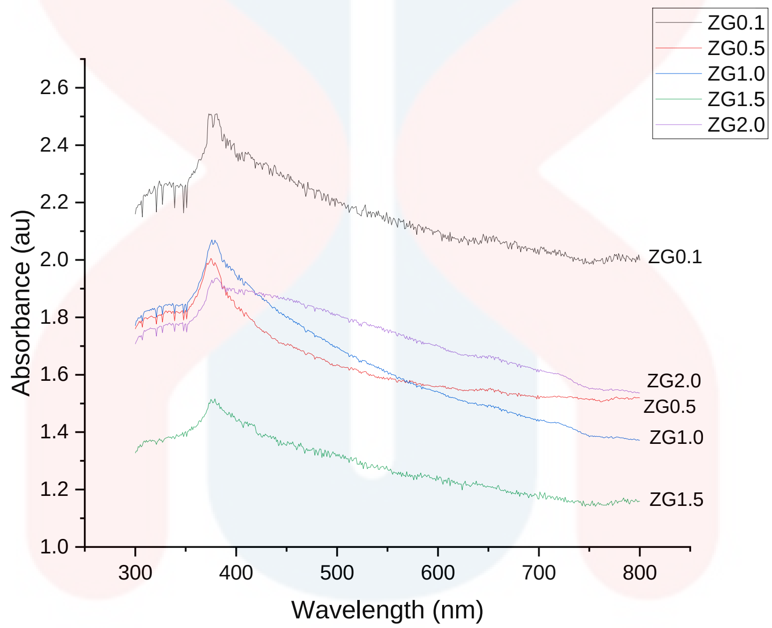


Figure 4.3: The UV-Vis graph spectra of ZnO nanoparticles prepared at different amount of GO via hydrothermal method.

4.3.1 Band Gap Determination

The energy band gap of ZnO with different total GO values was plotted using Tauc graph. The energy band gap is calculated from the Tauc relation formula as stated in Equation 4.2. The calculated data is then plotted in a graph of hν versus (αhν)2 through the absorption coefficient α related to the band gap Eg as $(\alpha hv)^{2} = k\ (hv - Eg)$. By extrapolating the linear projectile in the x-axis direction, the direct band gap of each ZnO/GO sample can be determined.

$$(\alpha hv)1/n = k\ (hv - Eg)$$

Equation 4.2

This equation is derived from Tauc and David-Mott relation refer to Equation 4.2, where α is absorption, hv is photon energy, k is the energy independent constant and Eg is the optical band gap. The exponent n is the nature of transition for direct band gap is 2 whereas for indirect band gap is ½.

$$Eg = hv$$

Equation 4.3

$$v = \frac{c}{\lambda}$$

Equation 4.4

$$Eg = \frac{hc}{\lambda}$$

Equation 4.5

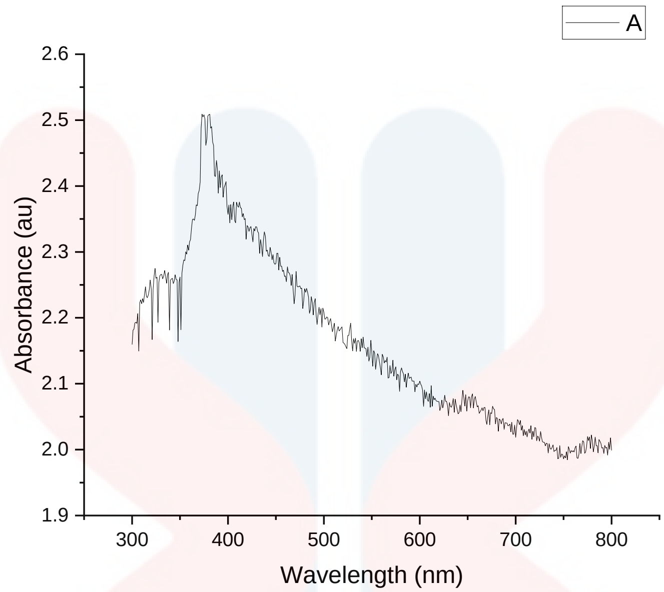
Max Planck equation (4.3) was used for conversion of wavelength to energy. Equation (4.4) inserted into equation (4.3) and equation (4.5) exists. Next, (αhv)n equation is used for y-axis which α is for absorbance coefficient and hv is used for photonic energy. Alpha (α) can be calculated by Beer Lambert's law that showed in Equation 4.6 below.

$$\frac{I}{I_0} = e^{-aI}$$

Equation 4.6

In this equation (4.6), I stand for the intensity of light that is transmitted, I_0 fr the intensity of light that is incident, stands for the absorption coefficient, and is the length of the rote along which the absorbance occurs.

(a)



(b)

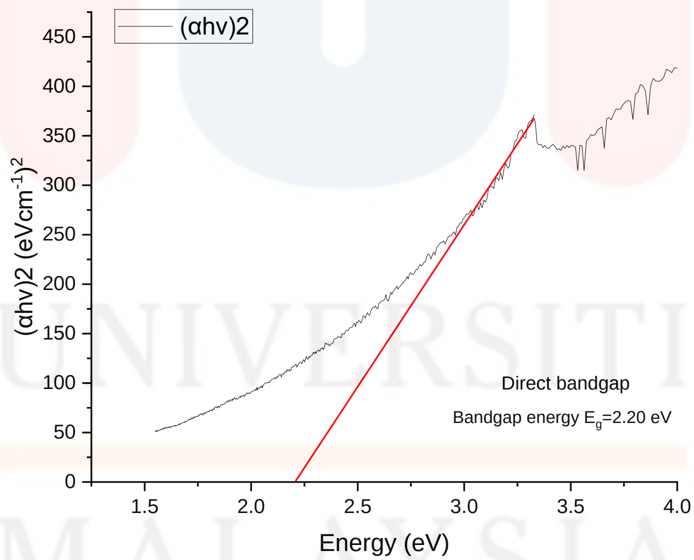
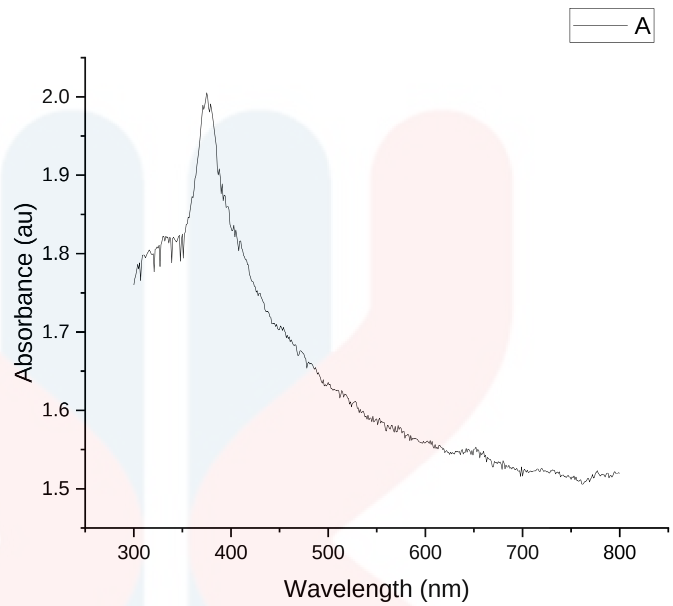


Figure 4.3.1: (a) The UV-Vis spectra of ZG0.1 nanostructure and (b) The Tauc Plot from UV-Vis analysis of ZG0.1 for the band gap

(a)



(b)

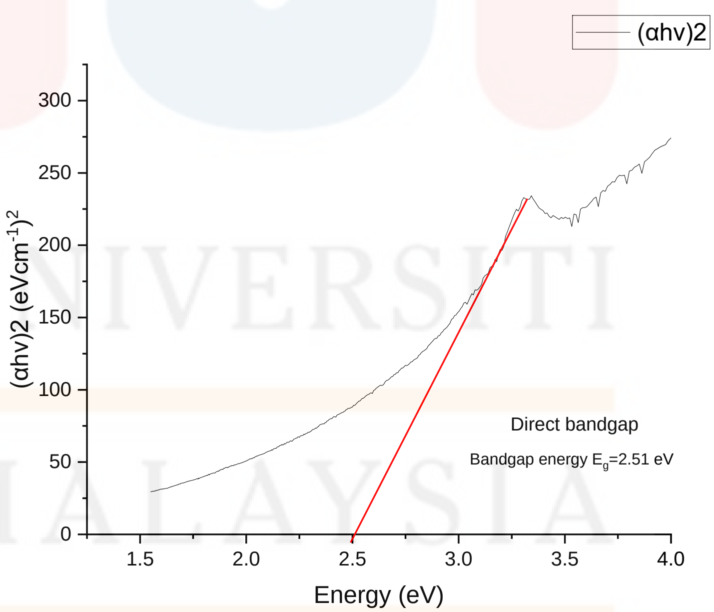
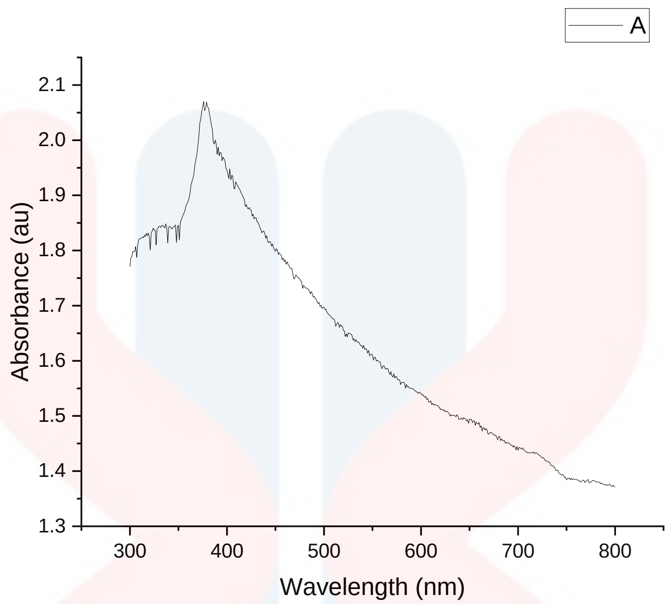


Figure 4.3.2: (a) the UV-Vis spectra of ZG0.5 nanostructure and (b) The Tauc Plot from UV-Vis analysis of ZG0.5 for the band gap

(a)



(b)

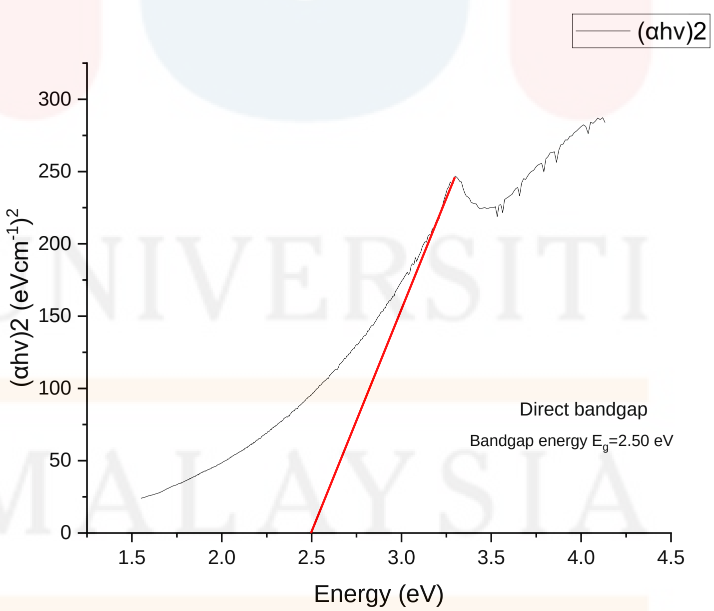


Figure 4.3.3: (a) the UV-Vis spectra of ZG1.0 nanostructure and (b) The Tauc Plot from UV-Vis analysis of ZG1.0 for the band gap

(a)

(b)

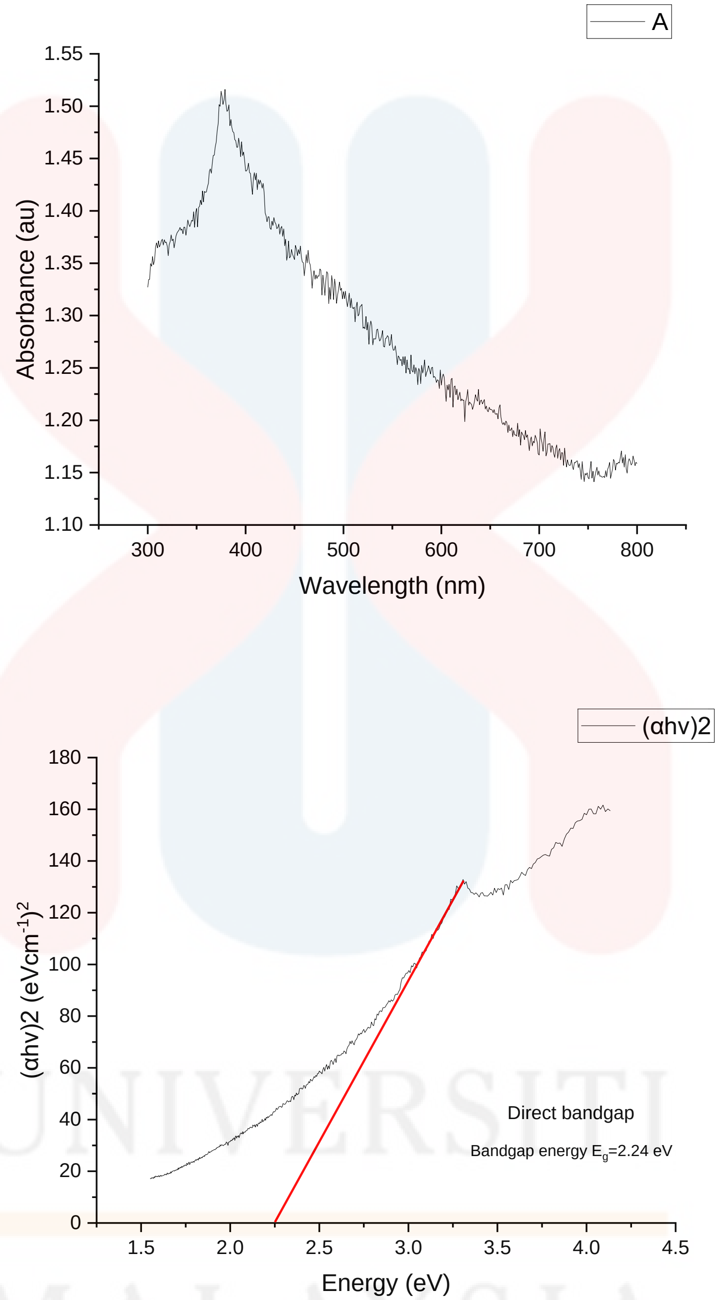
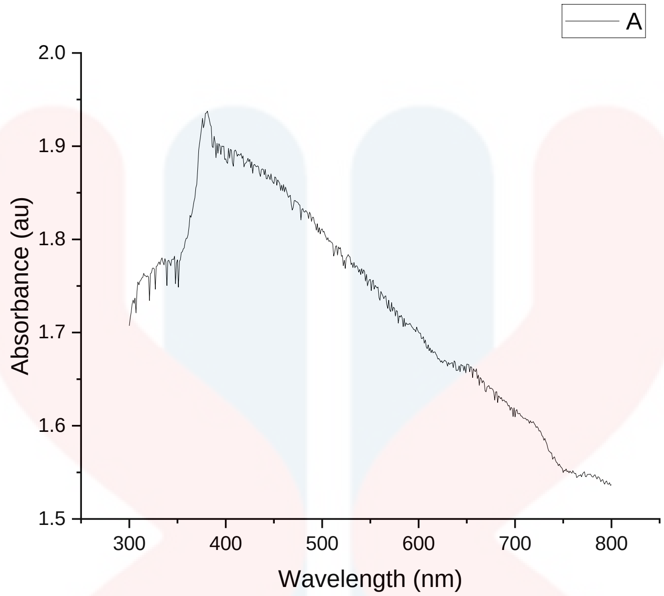


Figure 4.3.4: (a) the UV-Vis spectra of ZG1.5 nanostructure and (b) The Tauc Plot from UV-Vis analysis of ZG1.5 for the band gap

(a)



(b)

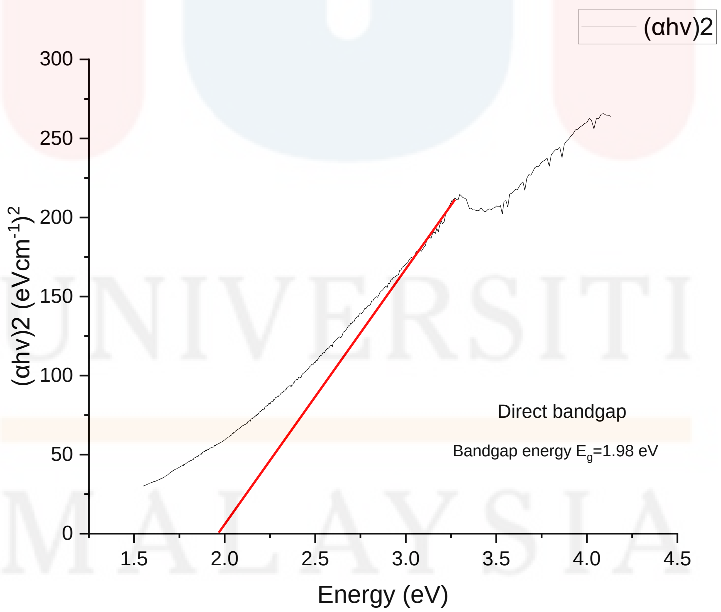


Figure 4.3.5: (a) the UV-Vis spectra of ZG2.0 nanostructure and (b) The Tauc Plot from UV-Vis analysis of ZG2.0 for the band gap

CHAPTER 5

CONCLUSIONS AND RECOMMENDATIONS

5.1 Conclusions

The investigation into the preparation of ZnO/GO composites using a hydrothermal method has provided valuable insights into the synergistic combination of these materials for semiconductor applications. By varying the amount of graphene oxide in the composite, the study has demonstrated the ability to control the structural and optical properties of the resulting materials. The findings highlight the potential for ZnO/GO composites to exhibit enhanced semiconductor capabilities, paving the way for the development of high-performance devices in optoelectronics, solar cells, sensors, and catalysis. The controllable and scalable nature of the hydrothermal process offers a promising avenue for further research and development in the field of Materials Technology. Overall, this research contributes to the advancement of semiconductor materials and sets the stage for future innovations in the realm of composite materials for various technological applications.

5.2 Recommendations

Based on the research conducted on the preparation of ZnO/GO composites using a hydrothermal method for semiconductor materials, several recommendations can be made to further advance this field. Firstly, it is recommended to delve deeper into the optimization of reaction parameters such as temperature, pressure, and precursor concentrations to fine-tune the morphology, crystallinity, and optical properties of the composites. This optimization process can lead to the development of composites with enhanced semiconductor properties for a wide range of applications. Secondly, exploring the performance of ZnO/GO composites in specific semiconductor device applications, including photovoltaics, optoelectronics, sensors, and catalysis, is crucial to understanding their potential in practical settings. Additionally, collaboration with researchers from diverse disciplines can uncover novel applications and synergistic effects of these composites in emerging technologies. Long-term stability studies are also recommended to assess the durability and reliability of ZnO/GO composites under varying environmental conditions. Lastly, sharing the research findings through publications and presentations will not only contribute to the scientific community's knowledge but also inspire further research and innovation in the field of semiconductor materials and composite technology.

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